INNOVATION FOR CLIMATE

ENERGY INNOVATION FOR A PROSPEROUS PLANET

April 2021

TERRA PRAXIS

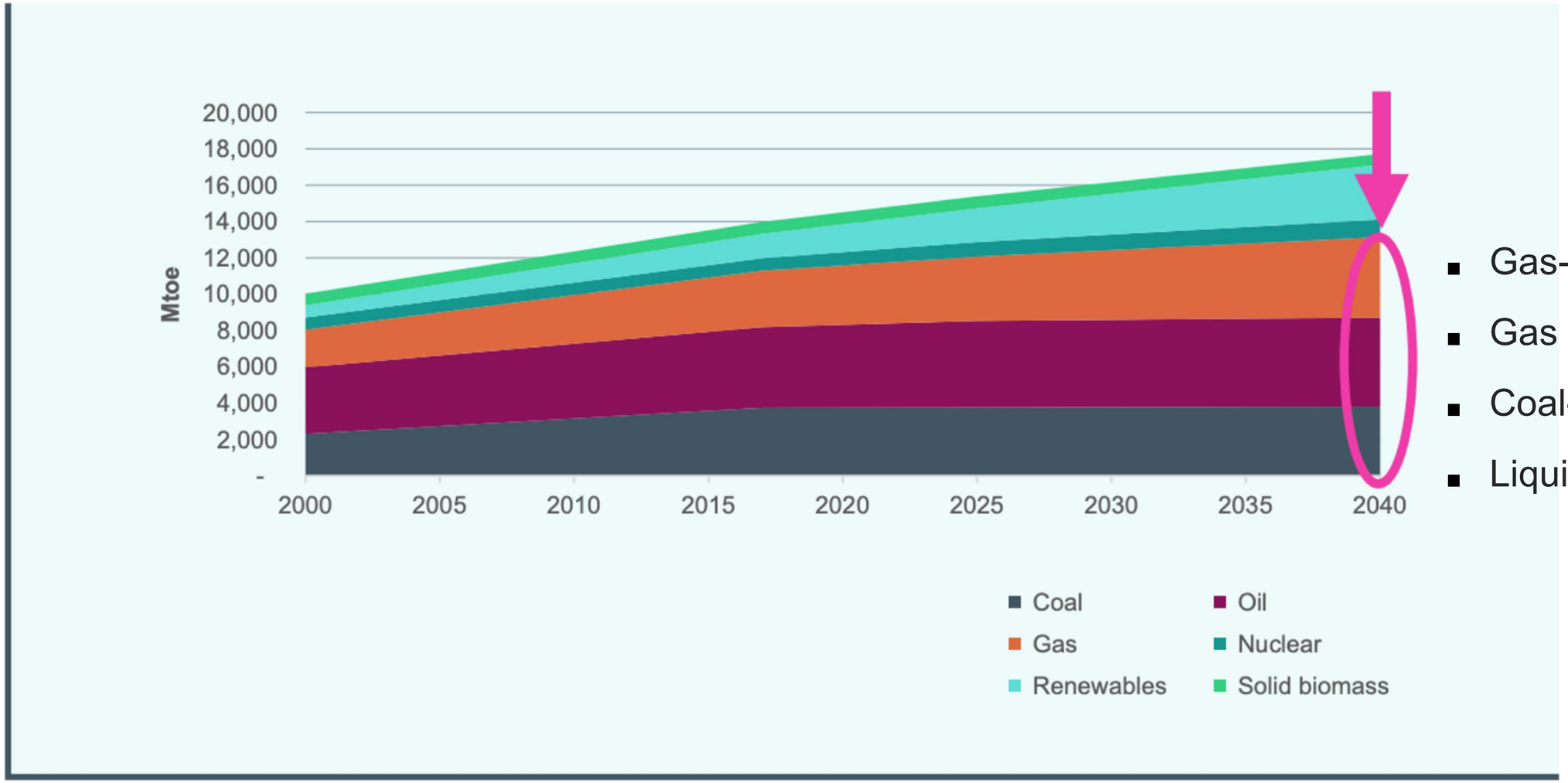
ABOUT TERRAPRAXIS

Goals: Prosperity and Decarbonization

Non-profit, with offices in US and UK, founded to develop and deploy ‘climate scale’ solutions. Focused on difficult-to-decarbonize sectors:

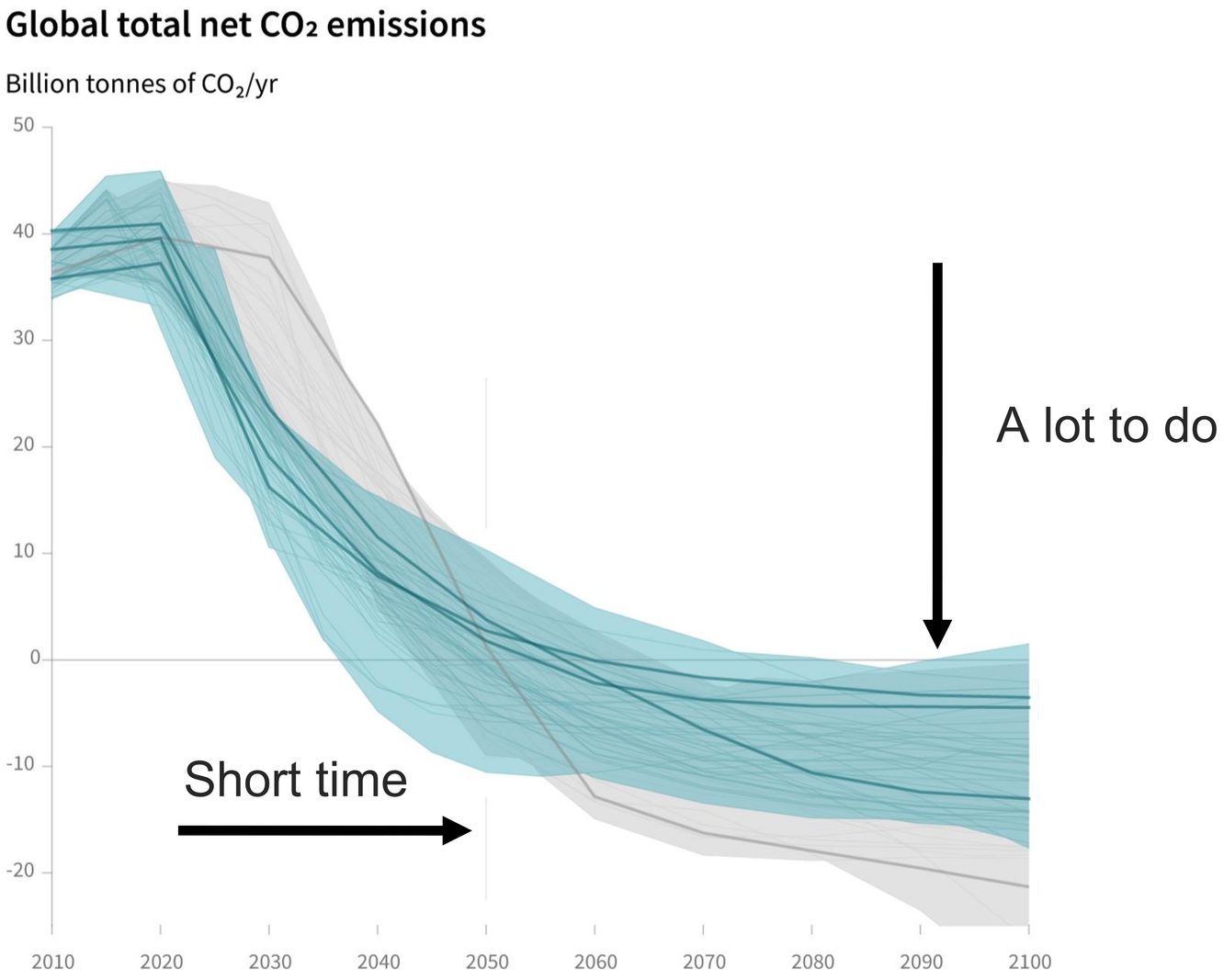
- Carbon neutral fuels for aviation, shipping, heavy transport
- Flexible power generation to complement renewables
- Coal plant repowering
  - $1.4 million Phase 1 project underway to develop cloud-based application
  - Outreach campaign to include Clean Energy Ministerial and COP26

Stated Policies Scenario: World Energy by Source (IEA 2018)



- Gas-fired power plants
- Gas for industry
- Coal-fired power plants
- Liquid fossil fuels

This is What We Need to Do



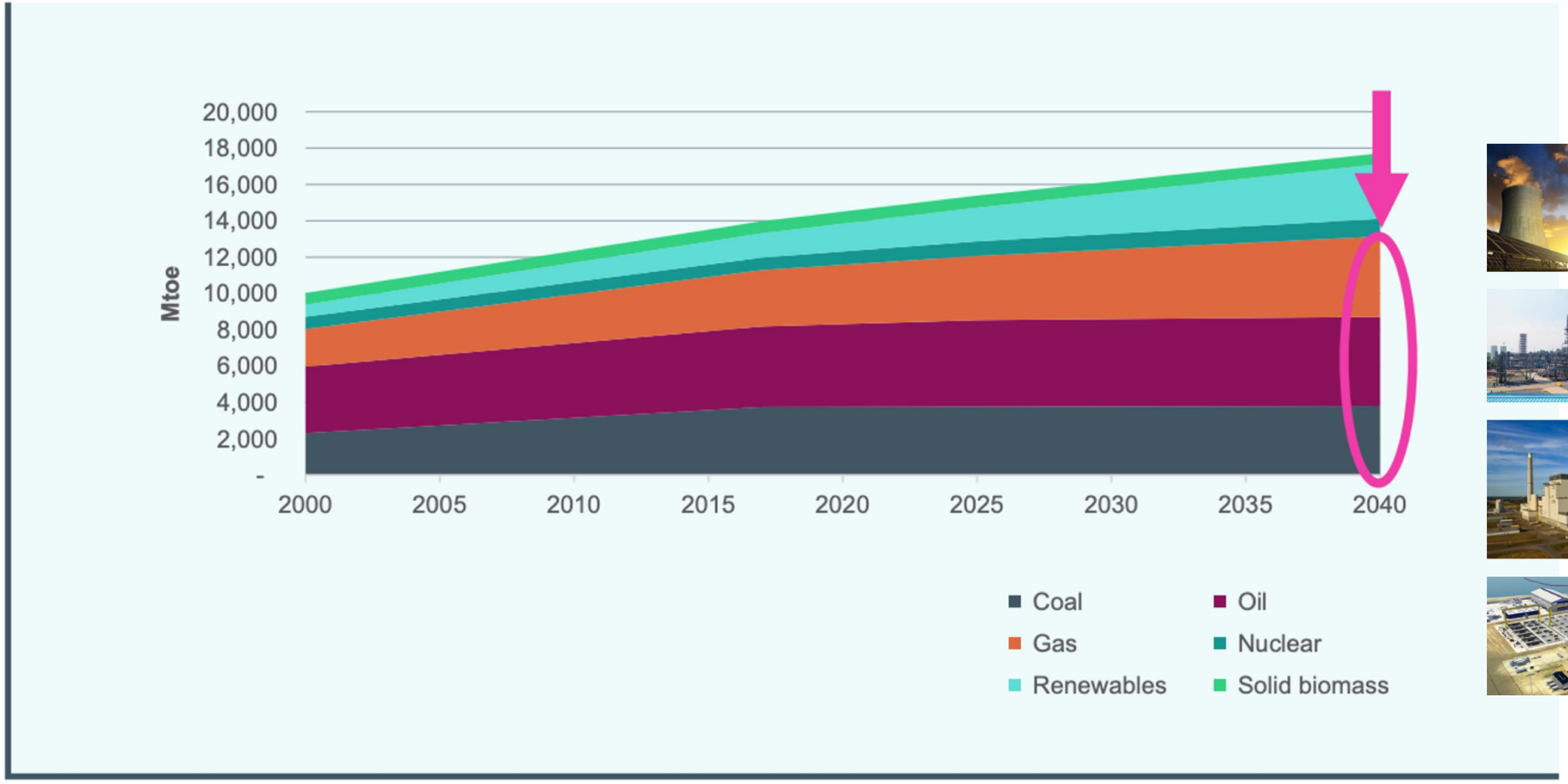
- Repower all coal plants
- Replace flexible gas plants
- Replace gas for industrial heat
- Replace liquid fossil fuels

While growing the energy system to supply the developing world

Our Climate Solutions need to be Impossible Burgers

- Drop-in substitute: cost & performance
- Leverages existing infrastructure
- Cost-competitive
- Not dependent on behaviour change
- Scale applicable to market size
- Rapidly deployable

Stated Policies Scenario: World Energy by Source (IEA 2018)



Impossible Burgers for Climate: Transformative Solutions

Flexible Generator – Electricity Market

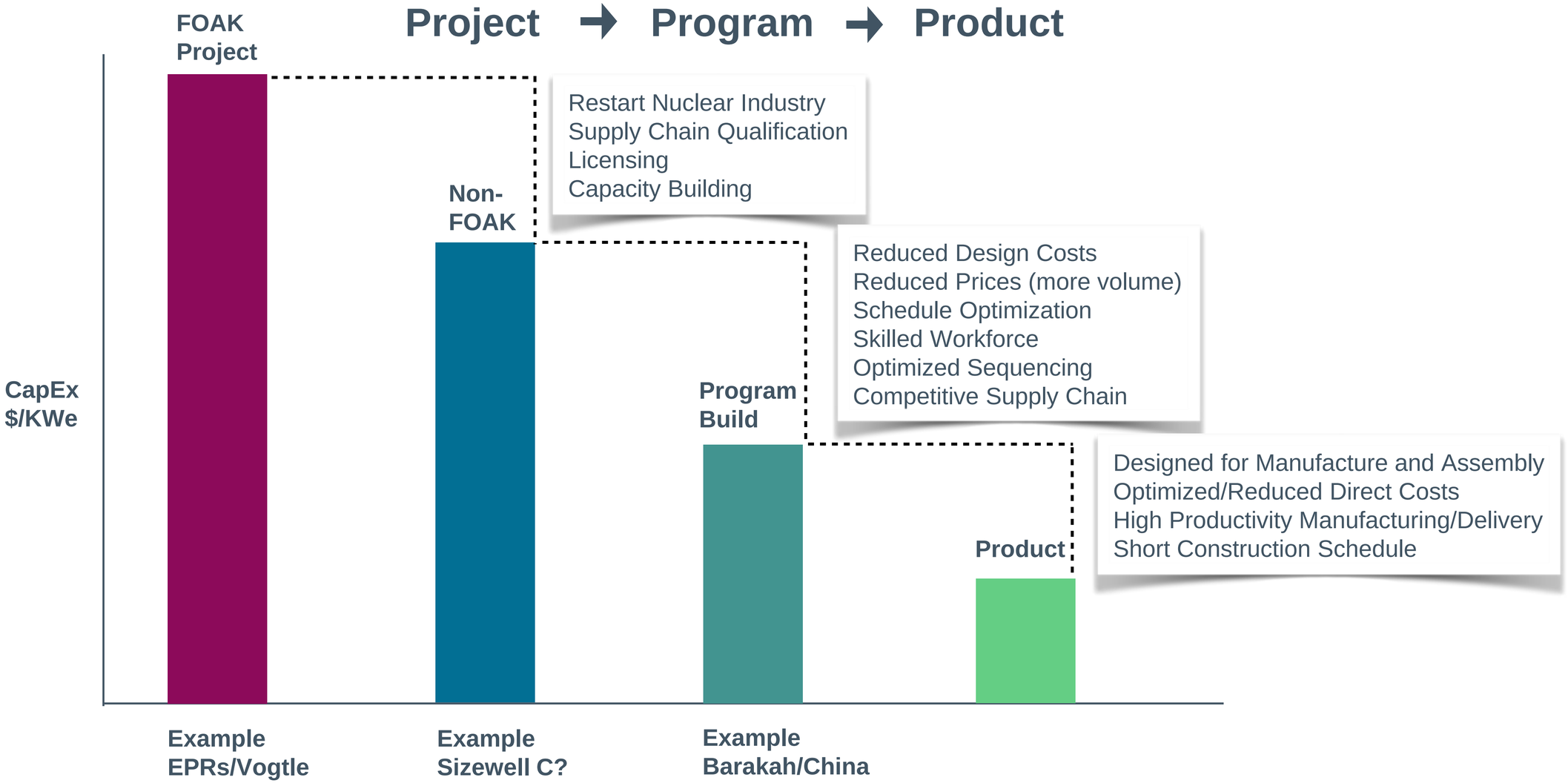
Hydrogen Cogeneration – Electricity & Fuels

Coal Plant Heat Source – Electricity Market

Hydrogen/Synfuel Gigafactory – Fuels Market

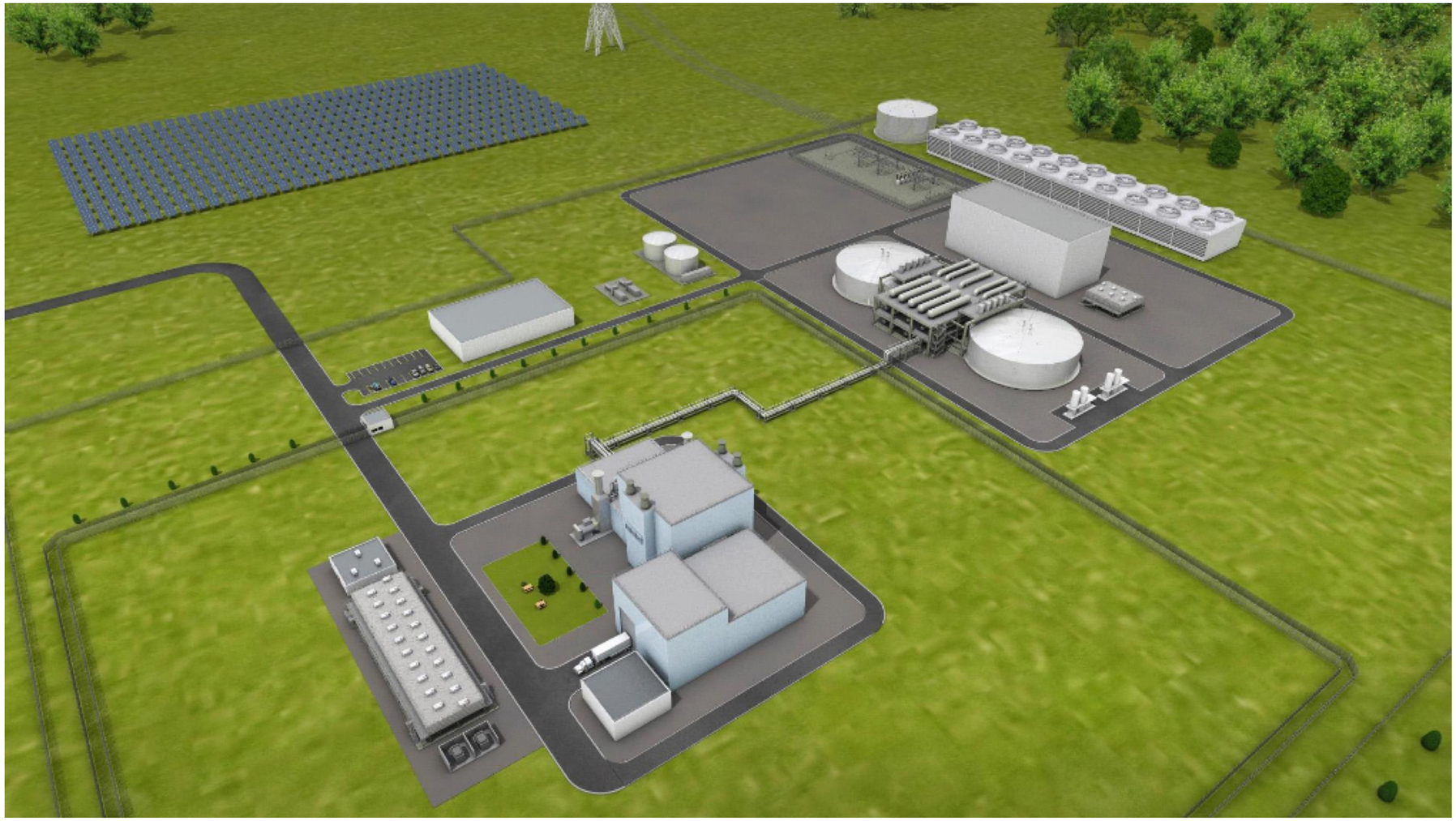
But wait, isn’t nuclear too expensive?

Pathway to Low Cost



Flexible Generation

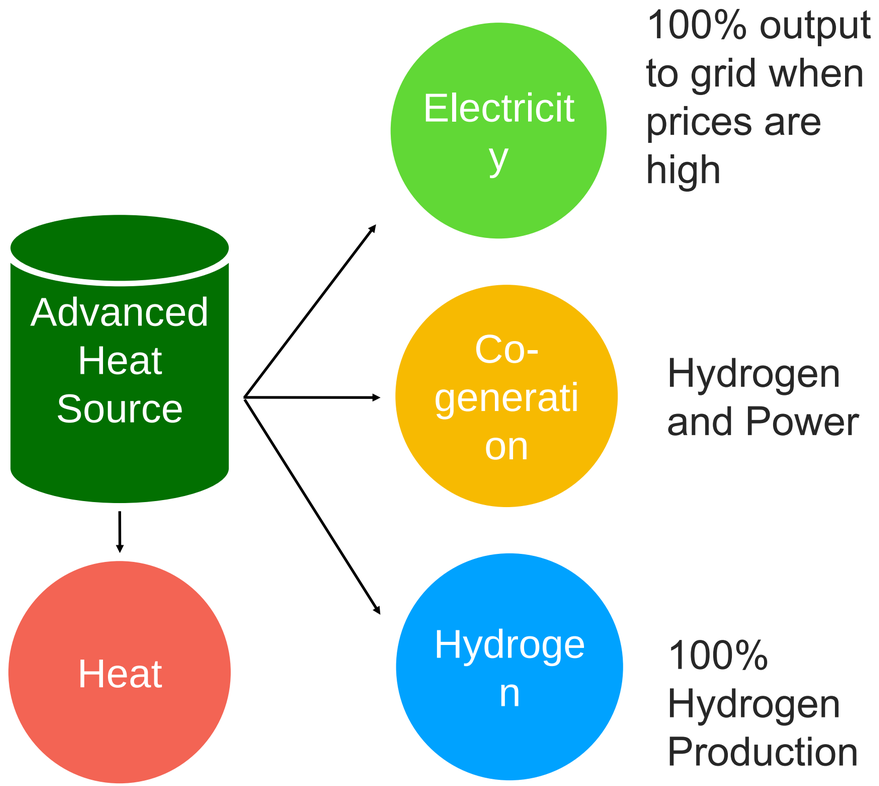
Nuclear Island separated from Turbine Island



Co-Generation

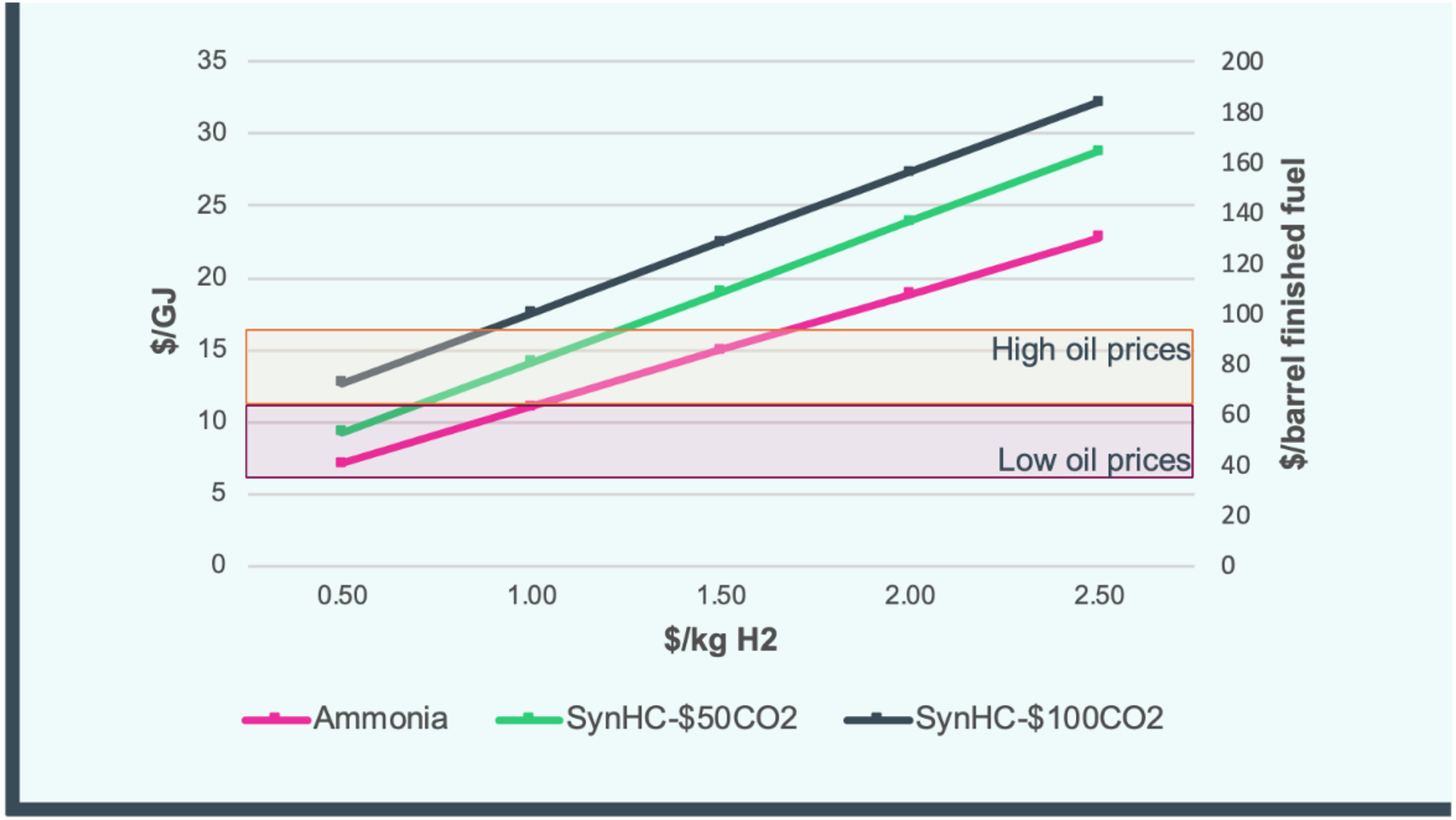
Flexible Cogeneration of Hydrogen and Power

Three modes of operation



Decarbonising Fuels

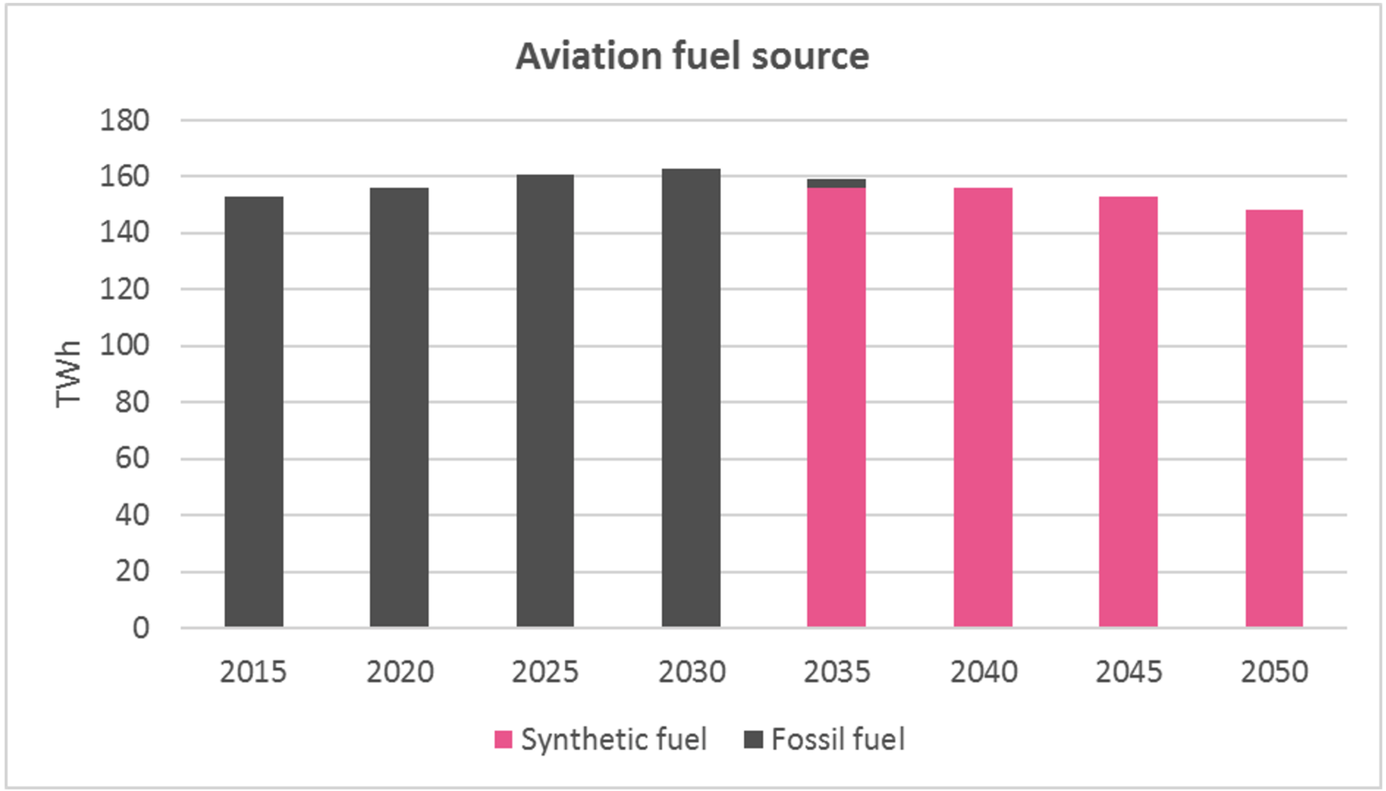
Cost: Oil price ‘guardrails’ of the hydrogen economy ($0.50–$1.50/kg)



Refinery-Scale Hydrogen/Synfuel Gigafactory

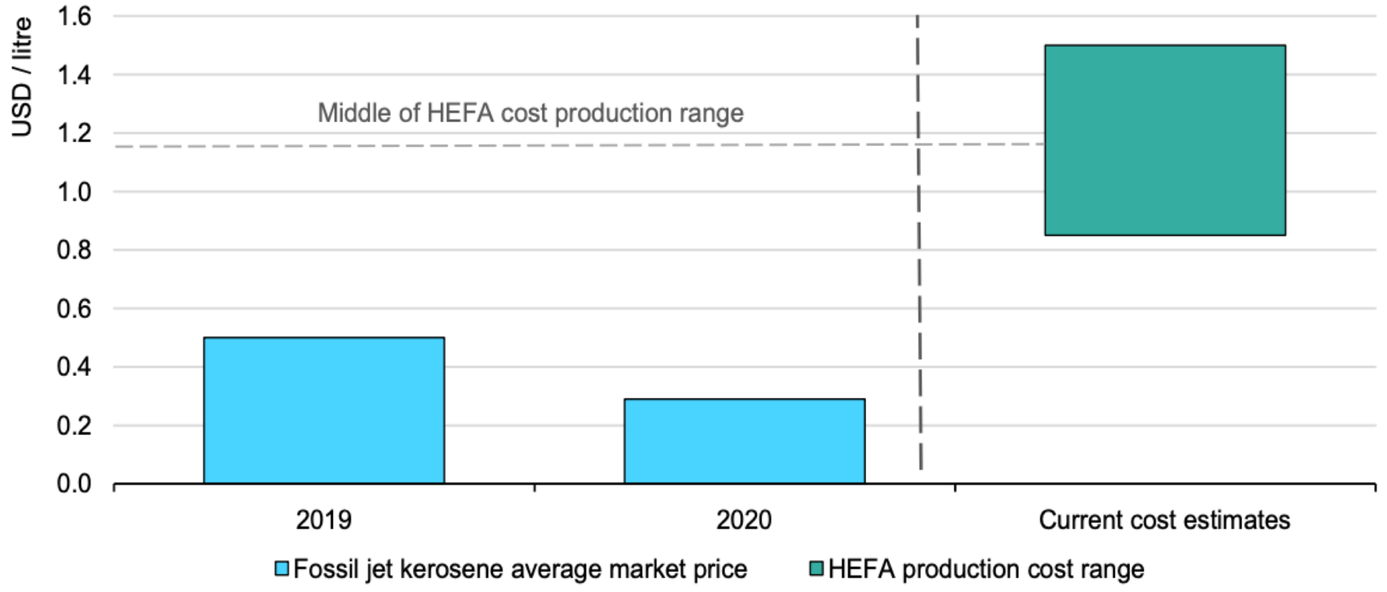
Hydrogen Gigafactory with Synfuel Plant Replaces Fossil Aviation Fuel

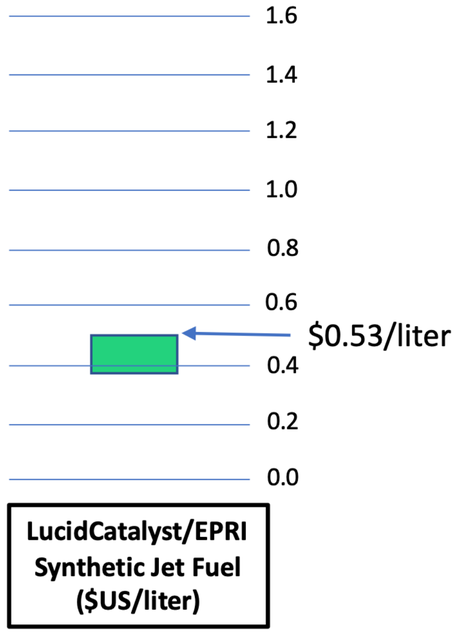
Liquid Synthetic Fuel Production - Run 310



IEA: Sustainable Aviation Fuel Projected Costs Compared to EPRI Synthetic Jet A Fuel

Figure 8.11 Fossil jet kerosene market price compared with HEFA aviation biofuel production cost





Source

Electric Power Research Institute (EPRI) Report: *Rethinking Deployment Scenarios to Enable Large-Scale, Demand-Driven Non-Electricity Markets for Advanced Reactors.* December 2020

Shipyard Construction of a Power, Fuels and Desalination Plant

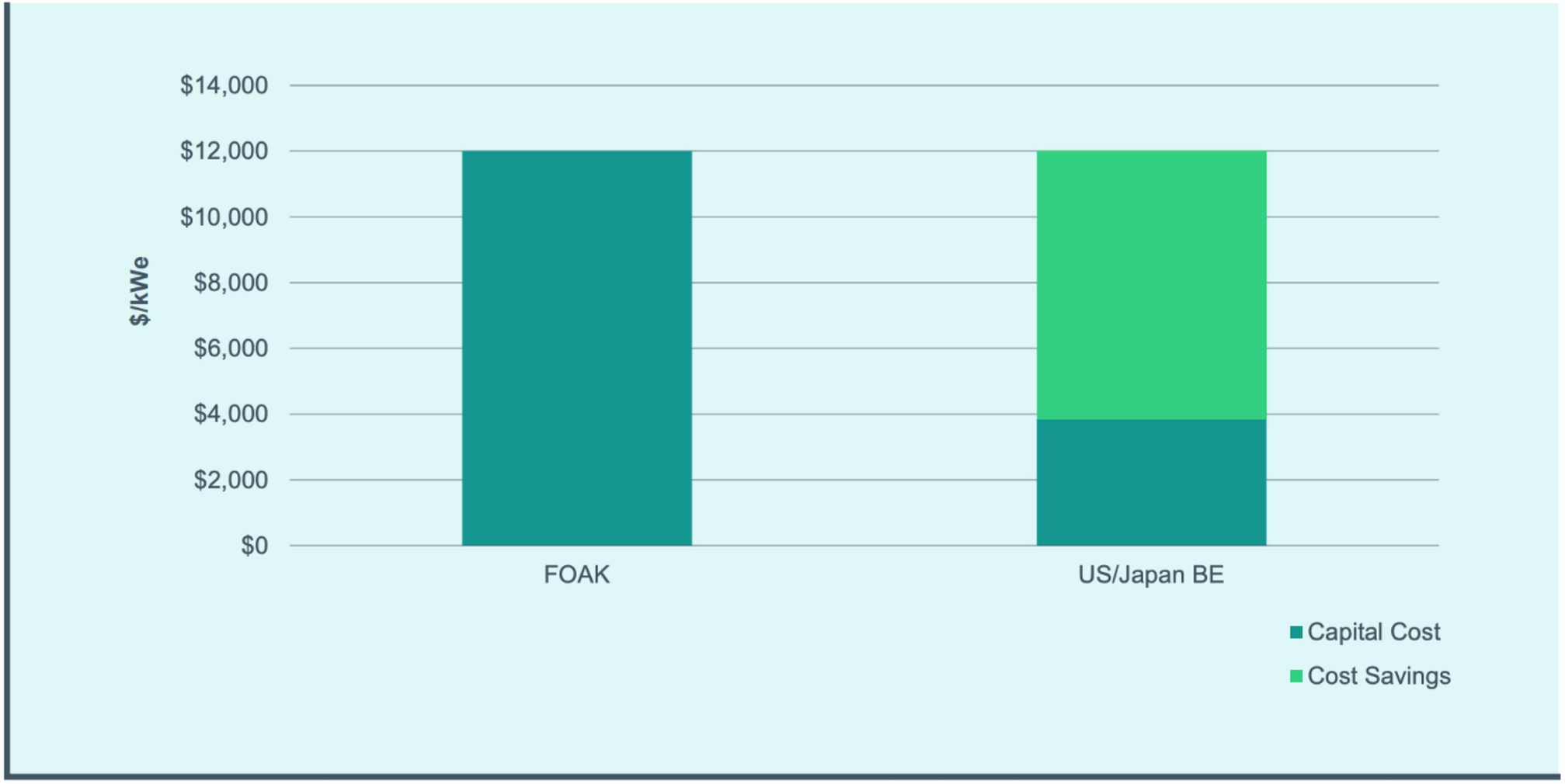
Modular blocks are added to an FPSO under construction in a dry dock.

Ammonia Bunker Offloading from a Production Platform

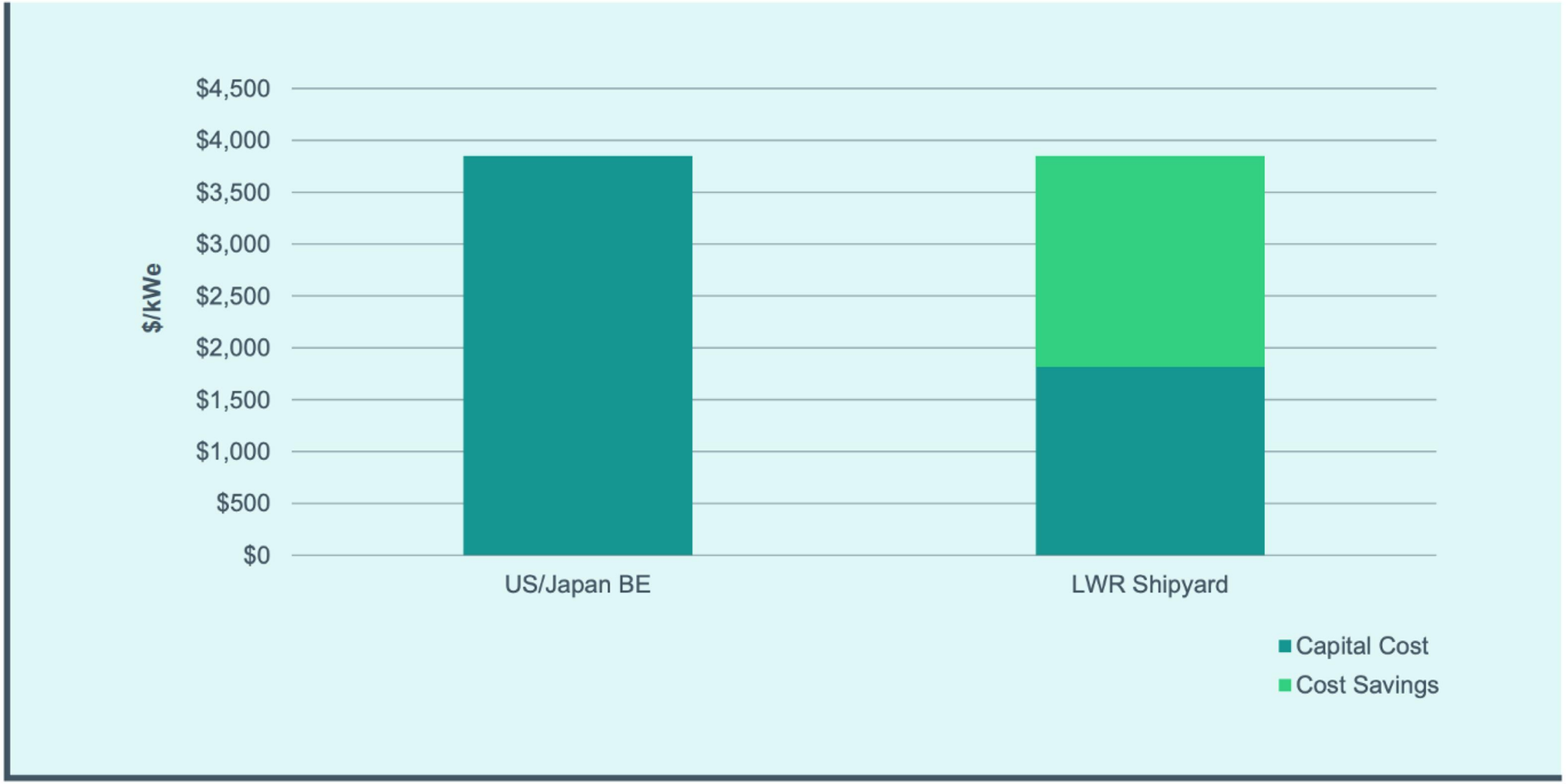
Multi-Product Platform Making Hydrogen, Power, Ammonia and Fresh Water

Climate Scale Constraints:
Cost, Speed, Scale and Space

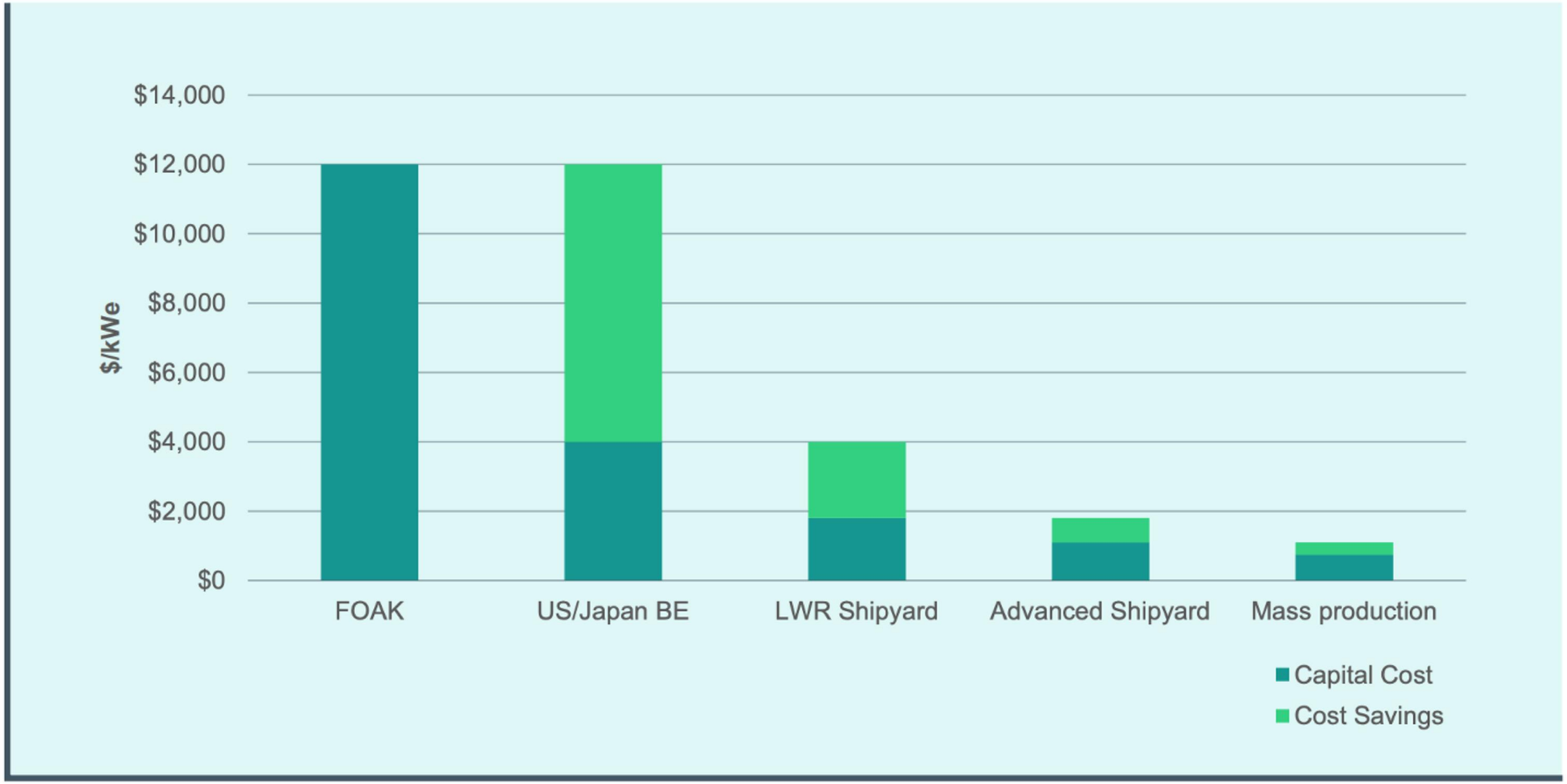
Cost Reduction from First-of-a-Kind (FOAK) to Program Build



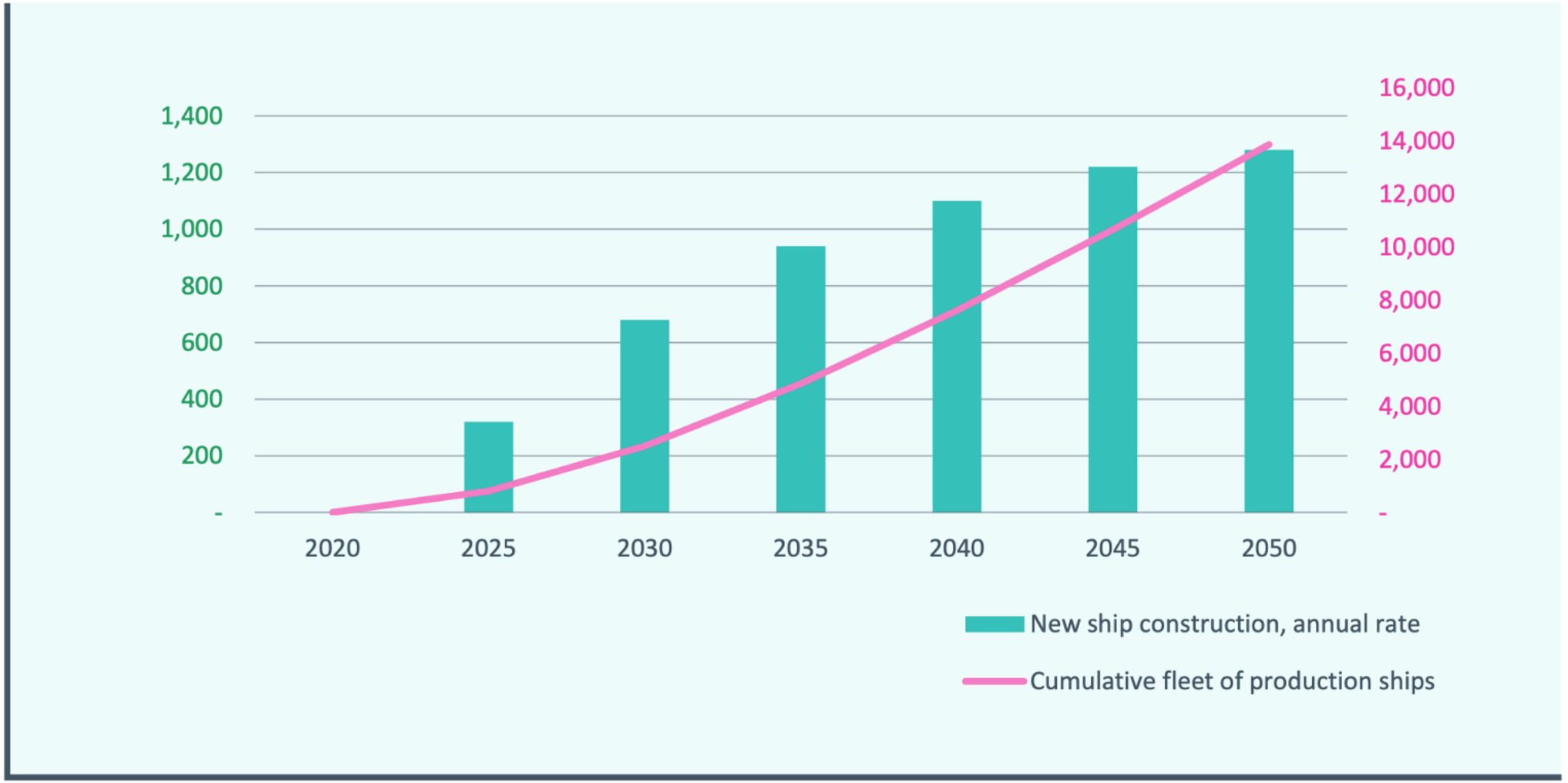
Program Construction to Shipyard Manufacturing



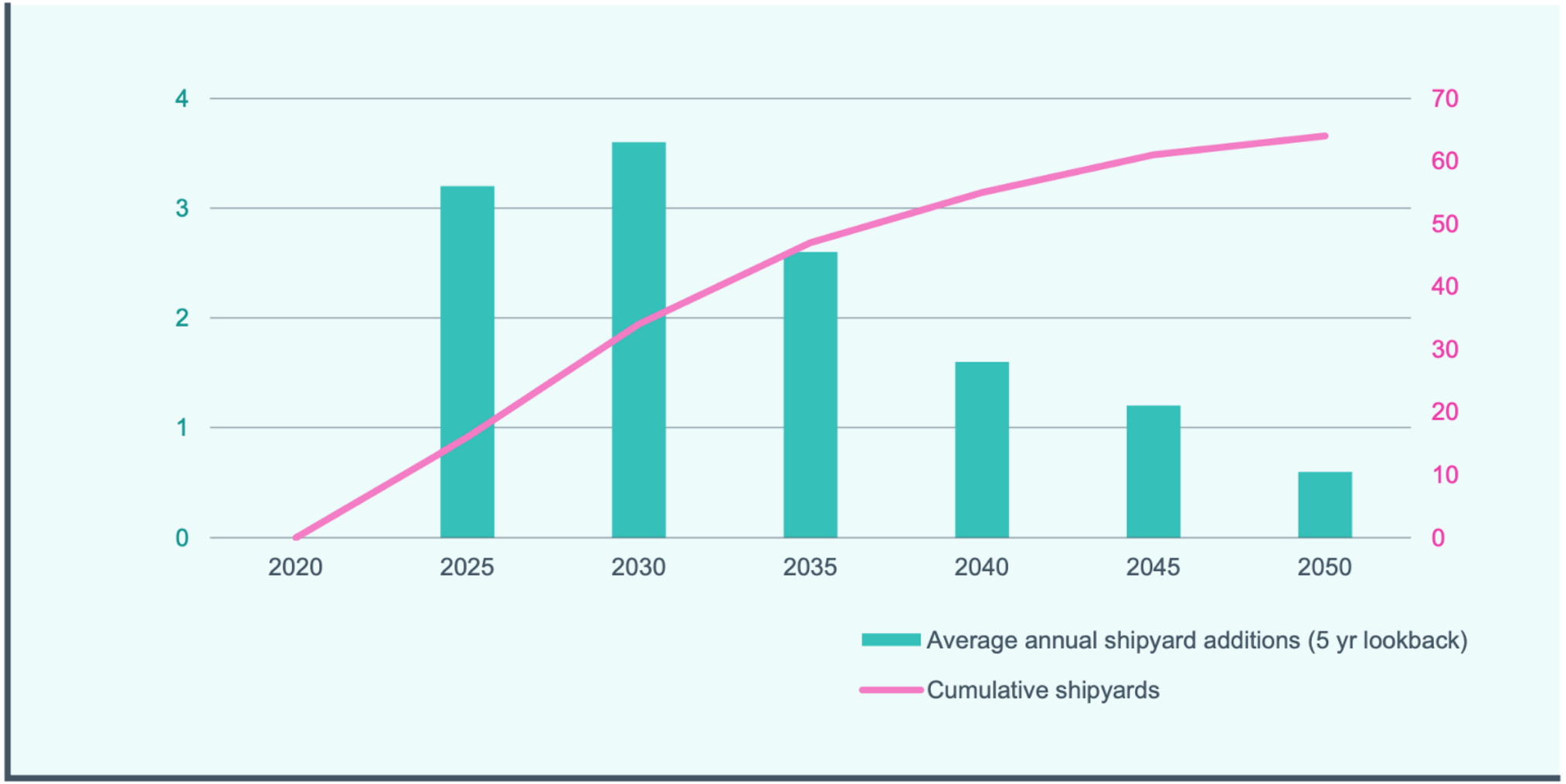
Evolution of Cost Reduction from First-of-a-Kind Construction Projects to Mass Manufactured Products



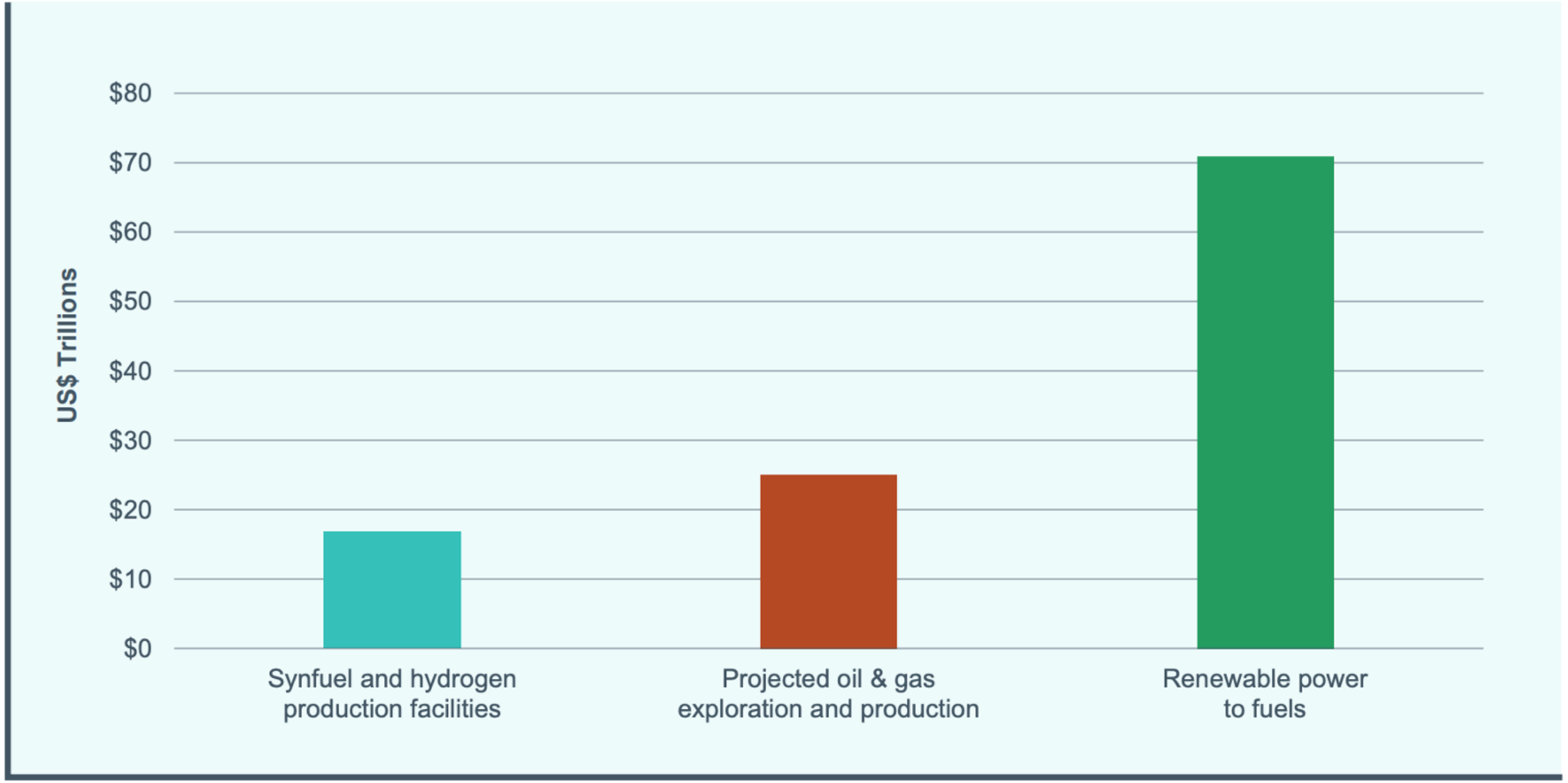
Additions and Cumulative Fuel Production Facilities



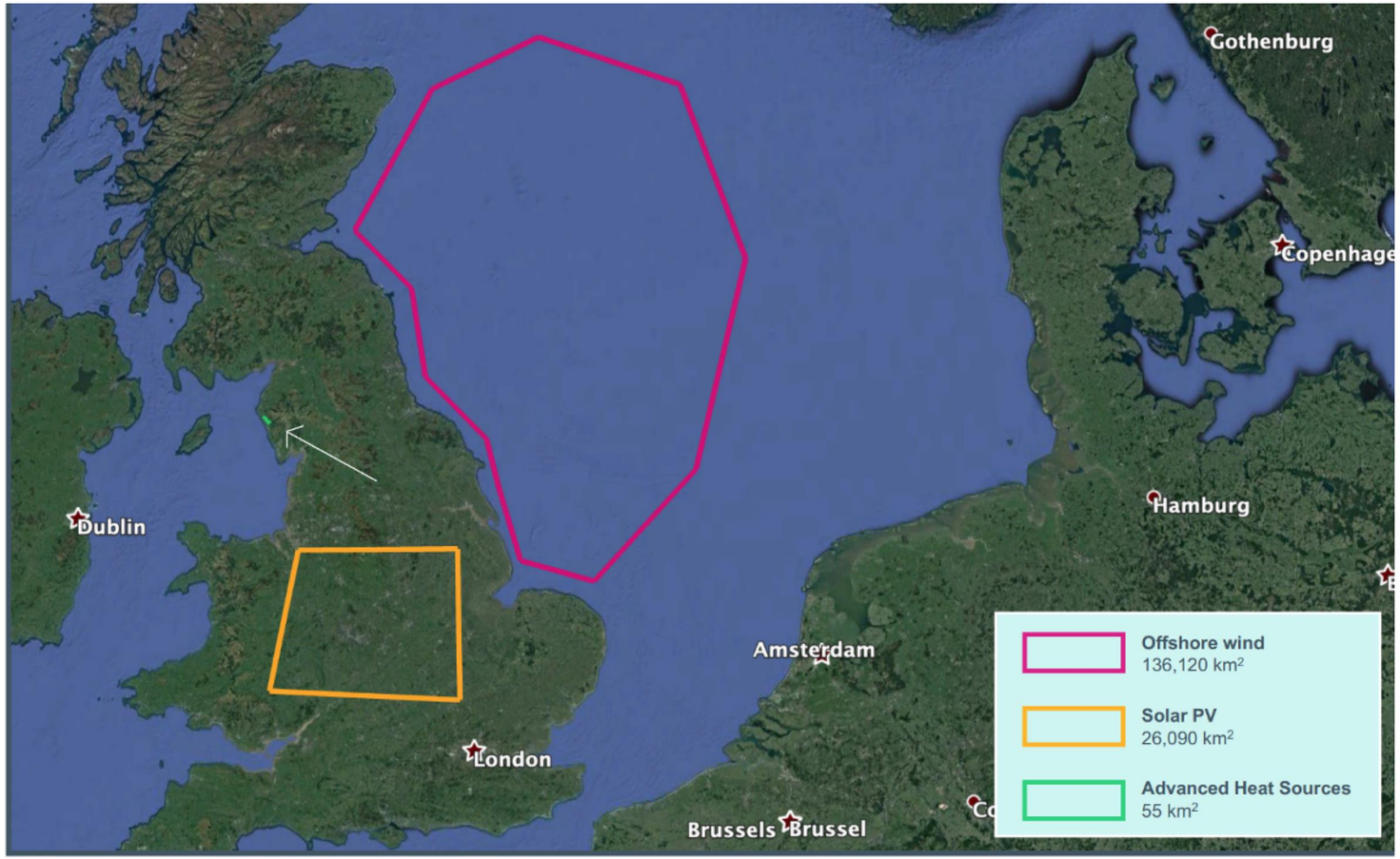
Shipyard Starts and Cumulative Operating Shipyards



Comparative Investment for Fuel Substitution by 2050



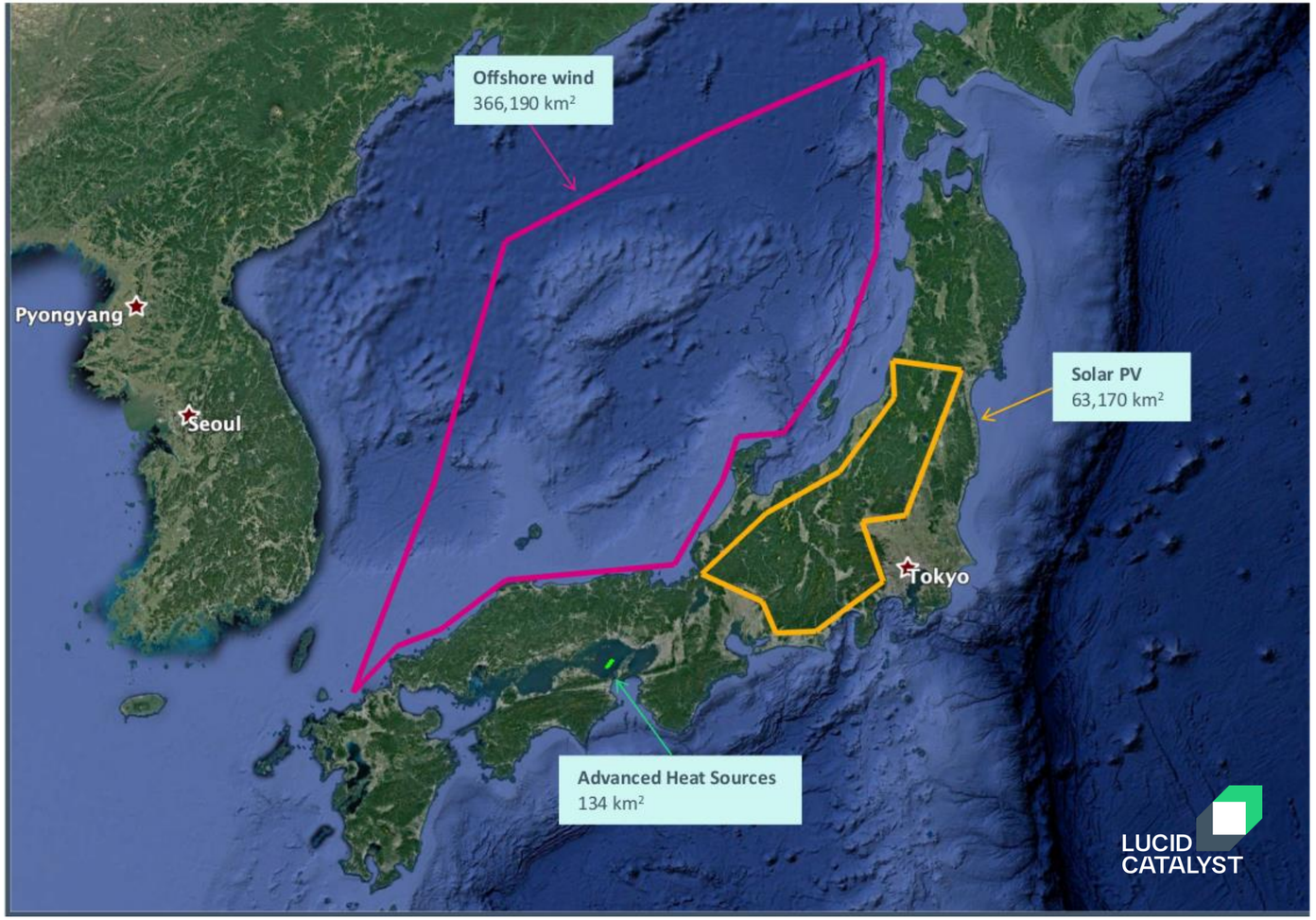
Land Area Requirements for Meeting Current UK Oil Consumption from Hydrogen



Each colored outline represents the total area that would be required for the siting of each type of resource if it were to be the only one used to generate enough hydrogen to replace current oil consumption in the UK.

Comparing area required to replace the UK's current oil consumption with hydrogen generated from either wind, solar, or advanced heat sources

Land Area Requirements for Meeting Japan's Current Oil Consumption from Hydrogen



Comparing area required to replace Japan's current oil consumption with hydrogen generated from either wind, solar, or advanced heat sources

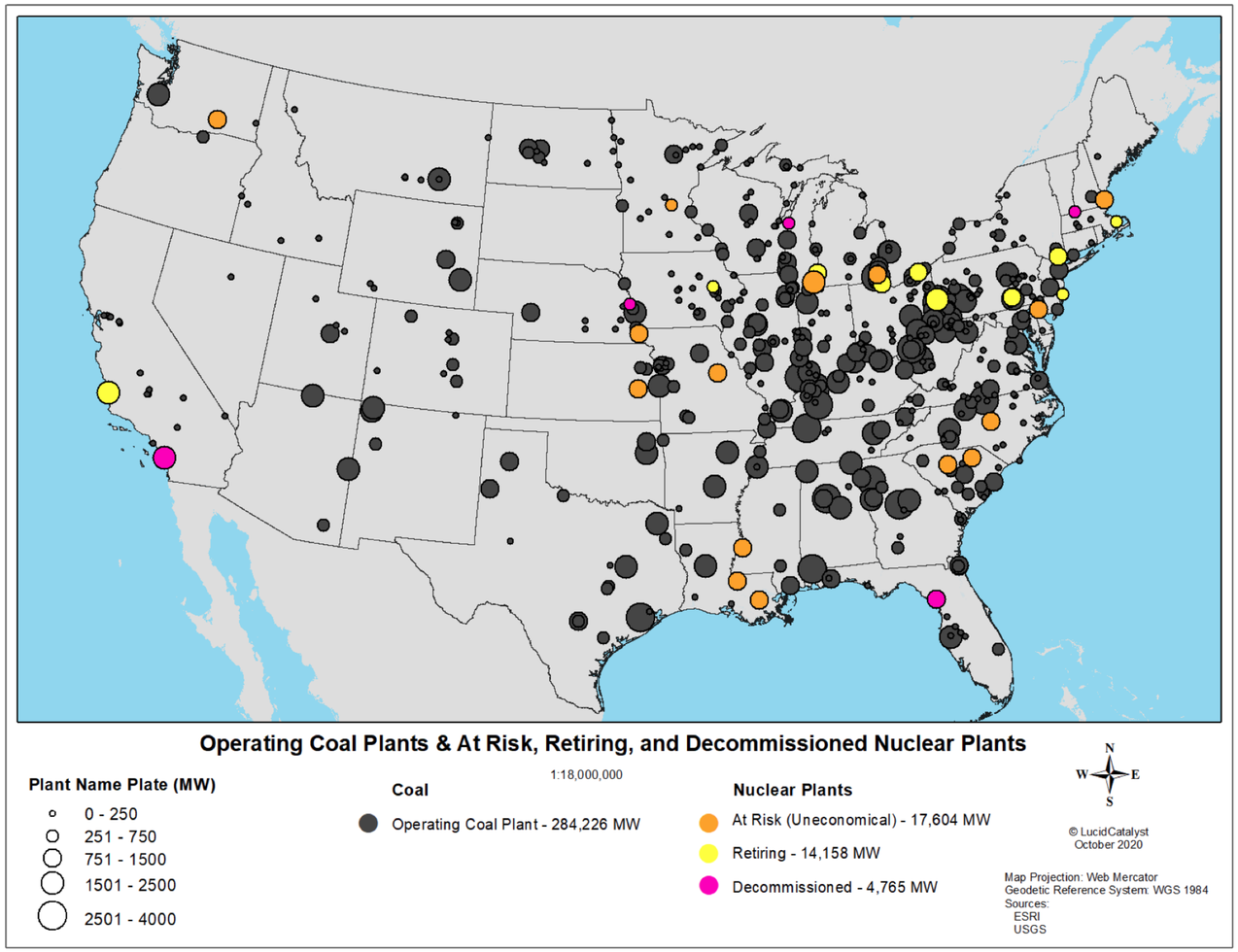
Re-Powering Coal

THE PROBLEM IN THE US

264 GW of Coal Plants in the US

- 23% of US electricity generation
- 47.5% average capacity factor
- 973 Million tons of CO_2/year (9% of global coal generation emissions)
- 60,000 jobs at power plants

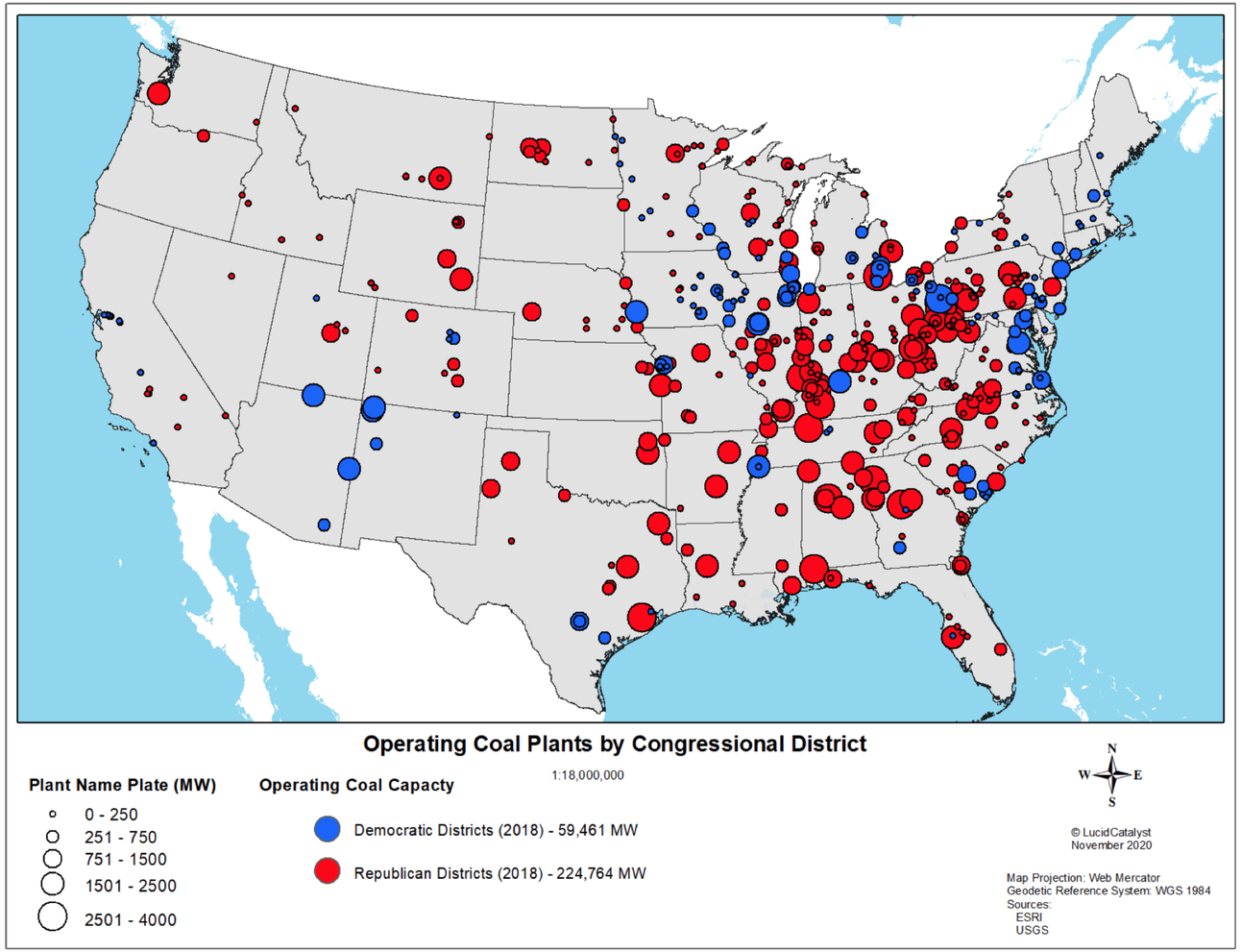
One 400 MWe coal plant produces 2-3 million tons of CO_2 per year



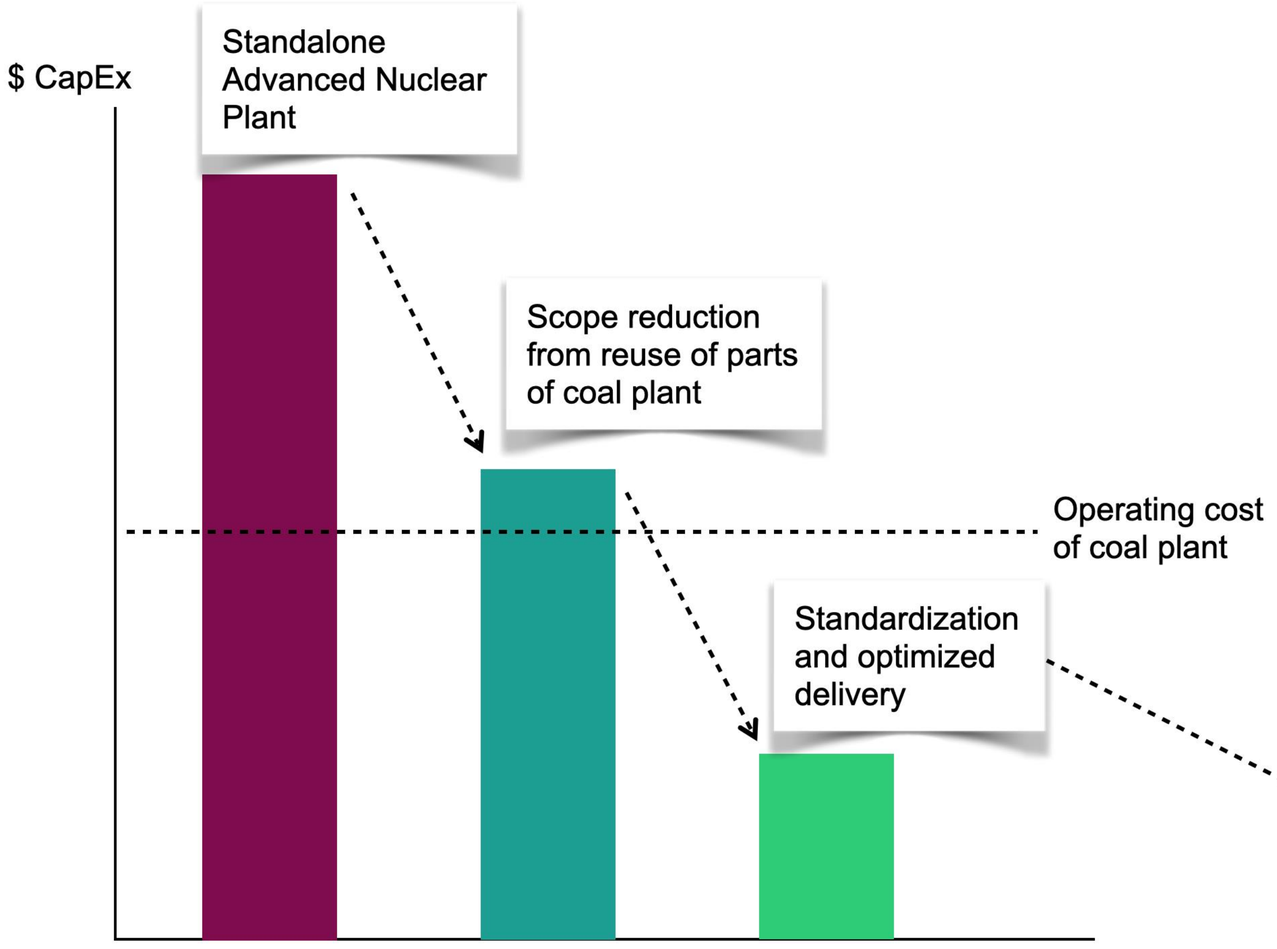
THE OPPORTUNITY

Repower 264 GW of Coal Plants

- Provide 20-40% of needed clean electricity for 2050 net zero with no new transmission build
- Eliminate 20% of 2019 emissions
- Preserve tax base/employment for small communities
- Enables just transition
- Radical improvement in public health
- GOP friendly-potential for bipartisan support

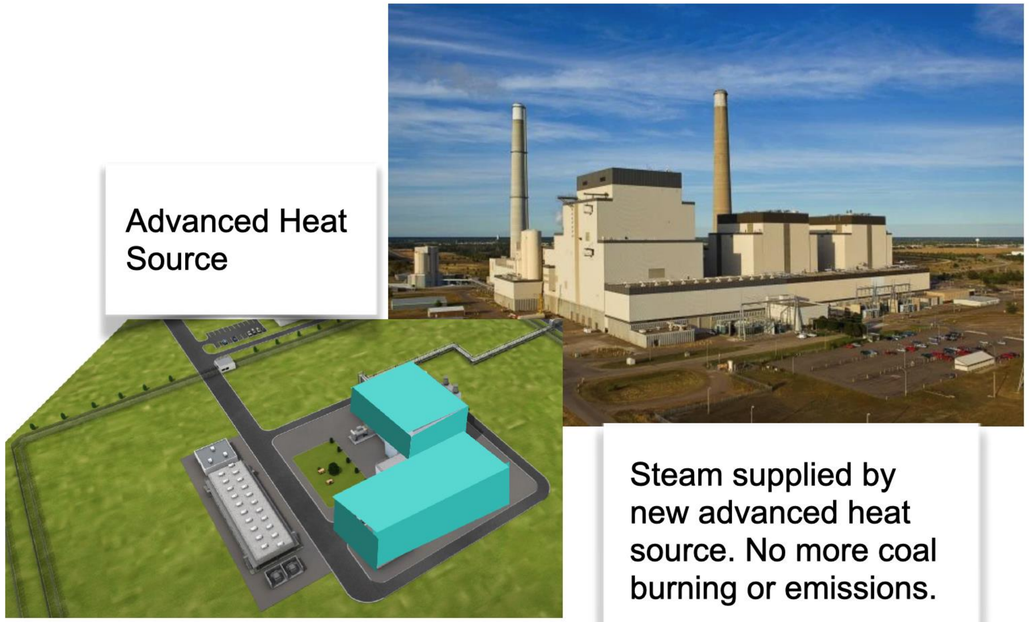


COST-COMPETITIVE COAL PLANT REPOWERING



Coal plant will be cheaper to operate after repowering with advanced heat source

Advanced Heat Source



Steam supplied by new advanced heat source. No more coal burning or emissions.

THE TEAM: TRANSFORMING A PROBLEM INTO AN OPPORTUNITY

- TerraPraxis has assembled a global team of leading experts to design a solution that meets the technical, financial, regulatory, and engineering requirements for repowering the majority of the global coal fleet — within the timeframe that is relevant to the climate challenge
- Advanced heat sources suitable for cost-effective repowering of coal plants coming to market in 2020's
- Algorithmically designed building system design enables simplified, streamlined licensing, feasibility assessments and siting for large-scale, rapid deployment
- $1.4 million Phase 1 project underway

Project Partners

Bryden Wood

NUVIA

MIT

University at Buffalo

ONTARIO POWER GENERATION

TVA

Tennessee Valley Authority

Southern Company

PURPOSE: REPOWER 2 TW OF COAL

- Repower 2 TW of coal capacity by 2050 with zero emissions advanced heat sources by 2050.
- Must be an attractive investment for plant owners, shareholders, investors.
- Based in a supply chain strategy that enables the pace and scale of full implementation: an average rate of ~100 GWe per year, i.e., converting 250 coal-fired power stations (400 MWe average) each year.
- Must include viable high-level licensing pathway for rapid global deployment at scale to be designed into the approach.
- Outputs from this project will be showcased at the Clean Energy Ministerial (CEM) in May 2021 and COP26 in November 2021. These events and the stakeholder engagement activities around them are major opportunities to communicate the transformational proposition to relevant parties.

ENERGY INNOVATION FOR A PROSPEROUS PLANET

Kirsty Gogan
kirsty.gogan@terrapraxis.org

Eric Ingersoll
eric.ingersoll@terrapraxis.org

TERRA PRAXIS